EFFECT OF SPLIT APPLICATION OF FERTILIZER ON YIELD, COMPONENTS OF YIELD, AND OTHER AGRONOMIC CHARACTERS OF RICE (IV).*

By

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The effect of split application of fertilizers has been under investigation at Chiayi Agricultural Experiment Station since 1963, with a simple objective of finding out whether the efficiency of fertilizer utilization could be further improved by manipulating the time of fertilization. Experimental results obtained so far indicated that split application of nitrogen and potassium fertilizers was generally effective in raising grain yield in both the first and the second crops of rice (Chang and Yang, 1964a,b; 1966), whereas split application of phosphorus fertilizer did not show any significant increase in grain yield of rice (Chang and Yang, 1964b). Similar results were also reported by Tsai *et. al.* (1965) and Tsai and Chen (1966) for nitrogen fertilizer and by Shen and Yuan (1964), and Feng and Kuo (1965) for potassium fertilizer. No significant difference was observed between the basal and split application of phosphorus fertilizer (Matsuo, 1948). Mitsui (1954) also suggested that sufficient amount of phosphorus fertilizer applied to rice as a basal dressing would be enough to cover the need for a maximum yield production.

An experiment designed to furnish information on the most favorable time of applying nitrogen and potassium fertilizers at various places of the island, was initiated in 1965 under the sponsorship of the Joint Commission on Rural Reconstruction with Chiayi Agricultural Experiment Station and all the 7 District Agricultural Improvement Stations cooperating. The purpose of this paper is to pressent a brief summary of the significant results obtained at this Station.

MATERIALS AND METHODS

Yield data were obtained for 4 successive crops, 1965 to 1966, inclusive, from an experiment in which a given amount of nitrogen and potassium fertilizers were applied to rice in a single application or in different combinations of split application as listed in Table 1.

* This experiment was supported by the Joint Commission on Rural Reconstruction under the projects of 65-C12-A-1653 (b-1) and 66-C12-A-1722 (b).

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Table 1. Treatments of fertilizer application*

Treatment	Element	Easal dressing	First top-dressing	Second top-dressing	Third top-dressing	Fourth top-dressing (Panicle fertilizaton)	Fifth top-dressing (Grain fertilization)
A	N**	100	—	—	—	—	—
B	N	50	50	—	—	—	—
C	N	25	—	—	75	—	—
D	N	34	33	33	—	—	—
E	N	30	—	40	—	30	—
F	N	25	—	—	40	35	—
G	N	25	—	—	40	25	10
H	N	25	—	—	40	25	10
	K	50	—	—	50	—	—
I	N	25	—	—	40	25	10
	K	25	—	—	50	25	—

* Basal dressing: One day befor transplanting.
First top-dressing: 10 days (1st crop) and 7 days (2nd crop) after transplanting.
Second top-dressing: 20 days (1st crop) and 14 days (2nd crop) after transplanting.
Third top-dressing: 30 days (1st crop) and 21 days (2nd crop) after transplanting (maximum tillering stage).
Fourth top-dressing or panicle fertilization: Panicle initiation stage of about 58 days (1st crop) and 37 days (2nd crop) after transplanting.
Fifth top-dressing or grain fertilization: Heading stage or about 86 days (1st crop) and 63 days (2nd crop) after transplanting.

** The whole amount of P_2O_5 was used as a basal dressing, and the relative amounts (%) of N and K_2O applied at different times were shown in Table 1.

The trial was located in Tai-tou-ken Farm of Chiayi Agricultural Experiment Station on silty clay loam, a light colored, moderately heavy-textured soil of typical rain-fed paddy in Chianan area. Soil samples were taken before each trial and the analysis was made by Taiwan Agricultural Research Institute. Table 2 shows the result of the analysis.

Chianung 242, a typical panicle weight type of Japonica rice variety was used in the test. The plant spacing was 22.5 by 22.5 cm, (approximately 20 hills per square meter), with 5 seedlings being transplanted at each hill. Ammonium sulphate, calcium superphosphate, and potassium sulphate were used as carriers of N, P_2O_5, and K_2O which were applied at the rate of 100, 50, and 50 kg per ha respectively. Climatic conditions were favorable for good rice growth during the test period.

The design of the experiment was a randomized complete block with 4 replications. Each plot consisted of 13 rows 20 hills long or an area 3 by 4.5 m from which 11 rows of 18 hills each or an area 2.5 by 4 m (10 m^2 or 1/1,000 ha) was hervested for yield determination. Plot borders were not included so that border effects could be minimized. Besides grain yield, data for heading date, plant height, number of panicles per hill, panicle weight, panicle length, weight of 100 grains, number of grains per panicle were also taken for the analysis of variance. Since data on four crops in two years were available, combined analyses were also made for the recorded traits so that their interactions between treatments and years in both the first and the second crops could be determined.

Table 2. Result of soil analysis

	Organic matter (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	pH
First crop. 1965				
Surface soil	0.94 (low)	145 (high)	90 (low)	6.6 (medium)
Subsoil	0.38 (very low)	45 (low)	88 (low)	7.2 (high)
Second crop, 1965				
Surface soil	1.64 (low)	242 (high)	149 (medium)	5.6 (low)
Subsoil	0.06 (very low)	65 (medium)	116 (medium)	6.7 (medium)
First crop, 1966				
Surface soil	1.40 (low)	210 (high)	88 (low)	5.7 (low)
Subsoil	1.20 (low)	123 (high)	60 (low)	6.9 (medium)
Second crop, 1966				
Surface soil	1.80 (low)	229 (high)	98 (low)	5.8 (low)
Subsoil	1.46 (low)	134 (high)	85 (low)	7.0 (medium)

RESULTS AND DISCUSSION

Effect of Time of Fertilizer Application on Grain yield and Its Components.

The average grain yields for the 2-year period are given for each treatment in Table 3. Combined analyses of variance made on the 2-year summary of data in both crops indicated that differences in treatment means were highly significant. Treatments F and C gave the highest yields in the first and the second crops respectively, whereas treatment D, the lowest in both crops. The curves of grain yield were, as shown in Figure 1, generally in parallel with those of panicles per hill, indicating that the increase in grain yield was caused primarily by the increase of panicles per hill. The combined analyses of variance for yield

Table 3. Effect of time of fertilization on grain yield and its components.

Treatment	Grain yield (kg/ha)		Number of panicles per hill		Nummber of grains per panicle		Weight of 100 grains (g)	
	First crop	Second crop	First crop	Second crop	First crop	Second crop	First crop	Second crop
A	5,868	4,492	12.2	8.5	135.0	156.5	2.92	3.02
B	5,352	4,493	11.1	8.5	139.0	154.5	2.98	3.11
C	5,975	5,135	12.4	10.4	133.3	147.2	2.93	3.06
D	5,227	4,430	10.6	8.3	132.9	152.6	3.01	3.04
E	5,658	4,652	10.5	9.7	141.1	164.8	2.99	2.95
F	6,065	5,125	12.3	10.8	144.7	162.1	2.91	2.94
G	5,646	5,028	10.3	10.1	142.7	156.0	2.86	2.99
H	5,742	5,071	11.4	10.1	137.9	164.3	2.98	2.97
I	5,624	5,052	10.8	9.9	136.5	162.6	3.01	2.99
Mean	5,684	4,831	11.3	9.6	138.1	157.8	2.96	3.00
LSD 5%	311	300	0.3	1.1	—	9.3	0.10	0.09
1%	415	400	0.4	1.5	—	12.5	—	—

* Data are means of 1965 and 1966 Crops.

components (Table 3) showed that differences in panicles per hill among treatments were significant at 1% level in both crops. Grains per panicle and 100-grain weight were not in close association with grain yield. However, treatments with top-dressings at panicle initiation stage and heading stage produced more grains per panicle, especially in the second crop.

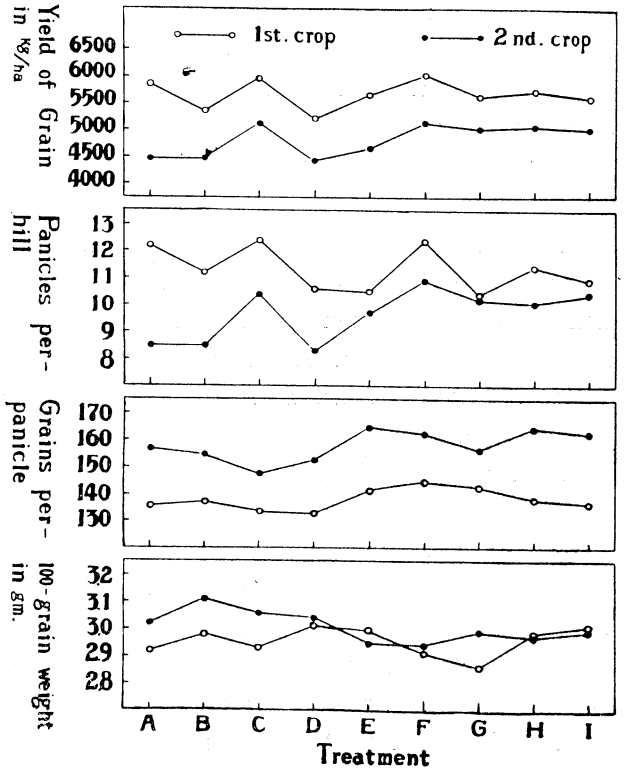

Figure 1. Effect of time of fertilization on yield and its components.

Treatment F produced 838 kg or 16.03% more grains per ha than that of treatment D in the first crop, whereas treatment C outyielded treatment D by 705 kg or 15.91% per ha in the second one, differances being significant at 1% level. The highest yield increases previously recorded for split application of fertilizers at Wang-tien-Li Farm of this Station were 5.69% and 6.36% for the first and the second crops respectively (Chang and Yang, 1966). Since soil fertility of Tai-tou-Ken Farm is lower than that of Wan-tien-Li Farm, split application of fertilizers appears to be more effective under the lower fertility conditions.

The differences in yields between treatments C and F were not significant, suggesting that both treatments had almost the same yielding ability. Treatment C had only one top-dressing of nitrogen at maximum tillering stage, whereas treatment F top-dressed twice at both maximum tillering stage and panicle initiation stage. The lowest yielding treatments B and C had one and two top-dressings of nitrogen respectively before maximum tillering stage which are very much similar to the conventional method of fertilization generally practiced by

farmers in Chianan area, and their yields are considered to be the typical ones for Chianung 242 obtainable at Tai-tou-Ken Farm. It appears, therefore, that yield increases of treatments C and F may be attributable to their proper timing of applying nitrogen fertilizer, and top-dressing of nitrogen at maximum tillering stage and panicle initiation stage are apparently necessary for increasing grain yield production. Similar results were also reported previously (Chang and Yang, 1966). As shown in Table 3. top-dressing of nitrogen at maximum tillering stage generally resulted in more panicles per hill, whereas that at panicle initiation stage or so called "panicle fertilization" appeared to produce more grains per panicle. This observation well agreed with those of Matsuo (1948). and Matsushima *et al.* (1964).

Top-dressing of nitrogen at heading stage or so called "grain fertilization" was practiced in treatment G, H, and I. Since grain yields of these treatments were all lower than that of treatment F, it seems likely that top dressing of nitrogen at heading stage may be unnecessary provided a sufficient amount of nitrogen is top-dressed at panicle initiation stage. Although nitrogen application at milk ripe stage was reported to be effective for yield increase (Matsuwura, 1962), it may be useful only under certain growing conditions as pointed out by Matsushima *et al.* (1963). The top-dressing of nitrogen at full heading stage was recommended by Matsushima and Tanaka (1967) to increase the percentage of ripened grains if the supply of nitrogen is withheld during the growing stage from 69 to 92 in leaf number index or about 42 to 18 days before heading. As shown in Table 5 the fertility percentages of treatments with nitrogen top-dressing at heading stage were not significantly higher than those without grain fertilization in this experiment. Nevertheless, the quality of rice grains can be greatly improved by top-dressing of nitrogen at heading stage. Tsai *et al.* (1965) reported that nitrogen or crude protein content of brown rice and milled rice increased 10 to 15% when the nitrogen fertilizer was applied at heading stage.

It is interesting to note that treatment A which applied all nitrogen as a basal dressing yielded as high as the two top yielding treatments C and F in the first crop whereas its yield was as low as the lowest yielding treatment D in the second crop. The seasonal difference in yield response of treatment A was further demonstrated by the partitioning of the treatment effect on grain yield as shown in Table 4. The component of the treatment effect, single versus split applications of fertilizers with one degree of freedom was not significant in the first crop, suggesting that nitrogen applied at one time during planting or split twice or more did not cause any significant difference in yield in the first crop, but in the second crop, the difference between single and split applications of nitrogen was significant at 1% level, indicating that split application of nitrogen was effective in increasing grain yield in the second crop. Moomaw (1965) also reported that Chianung 242 did not show any significant response to variously timed nitrogen applications in the 1963 and 1964 dry seasons (an equivalent of the

Table. 4. Mean squares and significance of F-values in the combined statistical analysis of data for the effect of time of fertilization on grain yield and its components.*

Certain degrees of freedom partitions		Grain yield (kg/ha)				Number of panicle per hill				Number of grains per panicle				Weight of 100 grains (g)			
		First crop		Second crop		First crop		Second crop		First crop		Second crop		First crop		Second crop	
Source	d.f.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
Treatments	8	591,999	1%	746,235	1%	5.46	1%	6.97	1%	136.99	—	287.63	1%	0.0225	5%	0.0025	5%
Single vs. split	1	304,934	—	1,034,204	1%	6.96	5%	11.59	1%	82.36	—	16.57	—	0.02	—	0	
Within split	7	633,008	1%	705,097	1%	5.25	1%	6.31	1%	144.79	—	326.35	1%	0.0229	5%	0.0257	1%
Years	1	559,858	—	164,642	—	46.56	1%	8.89	1%	2,278.13	1%	35.84	—	0.32	1%	0.09	1%
Treatments x Years	8	137,909	—	414,028	1%	1.15	—	4.39	1%	179.17	5%	80.03	—	0.0075	—	0.0025	—
Single-split x Years	1	2,504	—	786,843	1%	0.26	—	3.23	—	0.09	—	37.16	—	0.01	—	0	—
Within split x Years	7	157,252	—	360,768	1%	1.27	—	4.52	1%	204.75	5%	86.15	—	0.01	—	0.0014	—
Error	48	96,464		89,773		1.00		1.22		71.99		87.11		0.0096		0.0081	

* Analysis was based on data of the same crop seasons of 1965 and 1966.

first crop in Taiwan). The similar observation was also made by the writers in the previous report (Chang and Yang, 1966). Since panicles per hill is the most important component influencing grain yield, and rice plants generally produce more panicles per hill in the first crop, it appears necessary that more nitrogen should be applied at the early stage of growth in less splittings in order to prevent a drastic decline of effective tillers in the first crop. In the second crop, however, the environmental conditions are not favorable for rice plants to produce more panicles per hill, but are rather favorable for producing longer and heavier panicles with more grains per panicle, it seems desirable that nitrogen should by applied in more splittings with more emphasis placed at the late stage of growth.

Combined analyses of variance for grain yield and its components in Table 4 showed that differences between years were not significant in grain yields in both crops but they were mostly significant at 1% level in yield components. Interactions between treatments and years were highly significant only in grain yield and panicles per hill of the second crop, indicating that treatment effects on grain yield and panicles per hill varied with years. It seems reasonable, therefore, to suggest that environmental factors and nutritional status of rice plants should be taken into consideration when application of fertilizers is to be made.

Potassium fertilizer was split applicated in treatments H and I which gave slightly better yields than of treatment G which applied all potassium as a basal dressing, showing that split application of potassium fertilizer was slightly effective. Treatment I which applied more potassium fertilizer in top-dressings did not produce higher yield than that of treatment H which applied more potassium fertilizer at the basal dressing was found to give better yield by Feng and Kuo (1965). The grain yields of the treatments H and I, however, were all lower than those of treatments C and F, suggesting that the effect of split applicaton of potassium fertilizer is negligible when application of nitrogen fertilizer is not properly practiced.

Effect of Time of fertilizer Application on the Growth of Rice Plant and Some Agronomic Traits.

Plant height, number of tillers per hill, and leaf area were measured bi-weekly to determine the effect of time of fertilizer application on the growth of rice plant. Figure 2 shows that plant height increased as rice plant grew older. Plant height was not greatly affected by the time of fertilizer application in the early stage of growth, but it appeared to be closely associated with grain yield at the late stage of growth. Treatment means as shown in Table 5 differed significantly in both crops.

Rice plant showed a better growth with more tillers per hill in the early stage of growth up to heading stage when more nitrogen was applied at or before

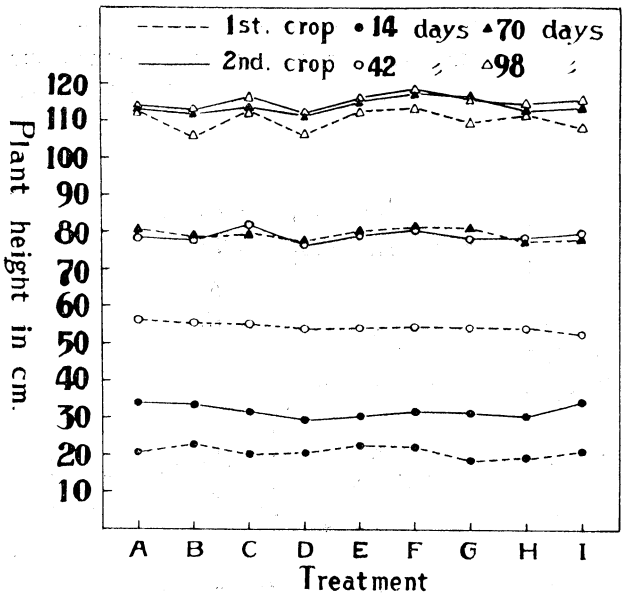

Figure 2. Effect of time of fertilization on plant height at different stage of growth.

Table 5. Effect of time of fertilization on some agronomic traits of rice.

Treatment	Heading date		Plant height (cm)		Panicle length (cm)		Panicle weight (cm)		Fertility (%)	
	First crop	Second crop	First crop	Second crop	First crop	Second crop	First crop	Second crop	First crop	Second crop
A	86	63	103.7	114.5	22.5	24.2	3.9	4.6	95.7	93.4
B	86	62	100.5	113.1	22.8	24.1	3.9	4.6	96.0	93.8
C	87	63	102.8	117.0	22.2	23.8	3.8	4.3	95.5	92.6
D	86	63	99.0	113.1	23.1	24.0	4.0	4.5	96.2	92.8
E	85	63	103.0	115.5	24.1	23.6	4.3	4.4	95.9	89.6
F	86	63	104.0	119.1	24.0	24.0	4.1	4.5	95.9	89.3
G	86	63	101.9	117.3	23.3	23.5	4.1	4.5	96.3	91.9
H	86	63	104.0	114.2	23.4	24.2	4.1	4.6	95.5	91.0
I	86	64	102.7	115.4	23.5	23.8	4.1	4.6	94.7	91.5
Mean	86	63	102.4	115.5	23.2	23.9	4.0	4.5	95.7	91.8
LSD 5%	—	0.6	2.7	3.7	0.5	—	0.2	—	—	2.0
1%	—	0.8	3.5	—	0.7	—	0.3	—	—	2.7

* Data are means of 1965 and 1966.

maximum tillering stage in the first crop as indicated in Figure 3. However, percentage of effective tillers was apparently lower in the treatments with early application of nitrogen as compared with that of the treatments which applied nitrogen lately. In the second crop, early application of nitrogen did not result in good tillering of rice plant, and treatments with nitrogen top-dressed at the late growing stage generally produced more tillers and panicles per hill. It is conceivable that early application of nitrogen is not effective in producing tillers and panicles which is the most important factor influencing grain yield in the

second crop, since tillering is largely controlled by water temperature (Matsushima *et al.*, 1964), and it is not unusual for water temperature during the tillering period in the second crop to outreach 31°C, the optimum temperature for maximum tillering.

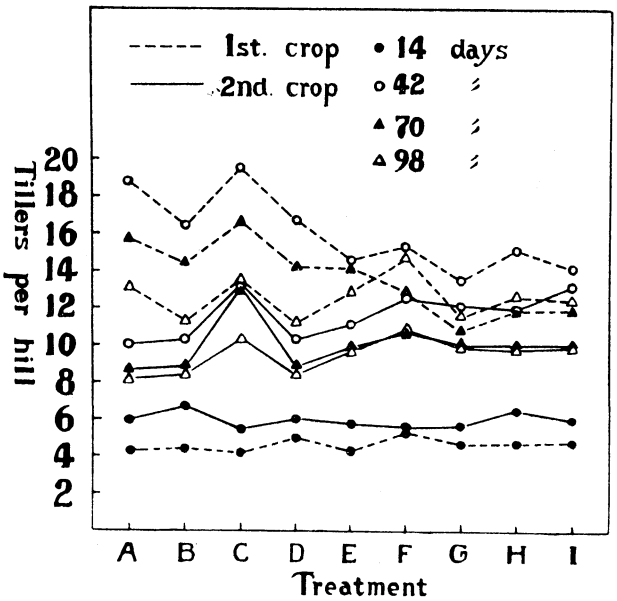

Figure 3. Effect of fertilization on tillers per hill at different stages of growth.

Figure 4 shows that leaf area index (LAI) increased as rice plant grew bigger, and reached its maximum somewhere around heading stage in both crops. The curves of LAI in Figure 4 were very much similar to those of number of tillers as shown in Figure 3, indicating that changes in LAI resulted primarily from changes in tiller number. Tanaka *et al.*, (1964) also reported that the tiller number per unit area was the major factor controlling LAI. It was observed that early application of nitrogen generally resulted in larger LAI in the second crop. The maximum values of LAI before heading were approximately 6 and 4 in the first and the second crops respectively, which were considered to be the right sizes for maximum dry matter production (Tanaka *et al.*, 1966). The optimum LAI for the rice plant has been reported to be between 4 to 4.5 by Kanda and Sato (1963) and 7 to 8 by Matsushima *et al.*, (1964). It seems highly likely that the response of LAI to the time of fertilizer application may have a great impact on the yield response, since treatments with larger LAI generally produced higher grain yield.

Table 5 shows that time of fertilizer application did not cause a significant difference in heading date in the first crop. However, late application of nitrogen significantly delayed heading date in the second crop. The fourth top-dressing of nitrogen or so called "panicle fertilization" was applied 58 days and 37 days after transplanting or 28 days and 26 days before heading in the first and the

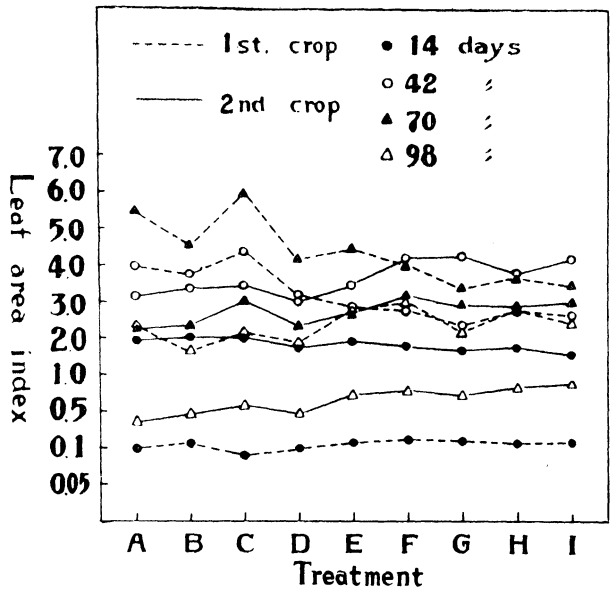

Figure 4. Effect of time of fertilization on leaf area index at different stages of growth.

second crops respectively. Matsuo (1966) also suggested that the suitable date for top-dressing at the time of ear-formation stage seems to be from 18 to 25 days before heading, depending upon the fertility of soil. The average length of young panicles at these stages were about 1 to 3mm as shown in Figure 5 which are in

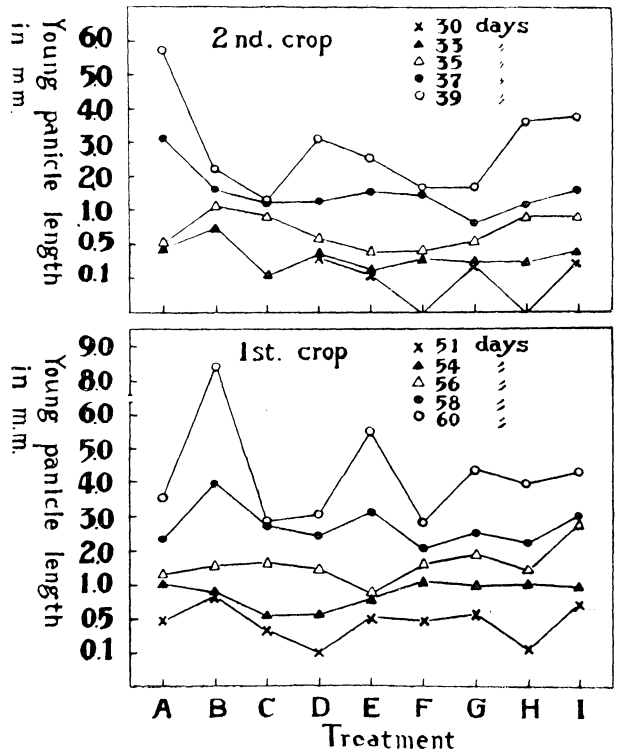

Figure 5. Growth of young panicles at their early initiation stage.

the early to middle spikelet differentiation stages (Matsustima, 1966). The stage when the length of young panciles nears 1mm is generally termed the beginning of panicle initiation, and the application of nitrogen at this stage has been proved to be highly effective in increasing grain yield production (Matsuo, 1948; Suzuki, 1958; Mitsui, 1964).

Nitrogen top-dressed at the later stages of growth produced longer and heavier panicles in comparison with the early top-dressings of nitrogen in the first crop, differences among treatment means being significant at 1% level. In the second crop, however, time of fertilizer application did not cause any significant changes in both panicle length and panicle weight. Combined analyses of variance given in Table 6 indicated that mean squares associated with years were highly significant in heading date, plant height, panicle length, panicle weight and fertility percentage in both crops. Interactions between treatments and years were not significant in most of the traits.

Table 6. Mean squares and significance of Fvalues in the combined statistical analysis of data for the effect of time of fertilization on some agromic traits of rice.

Certim degrees of freedom partitions		Heading date		Plant height (cm)		Panicle length (cm)		Panicle weight (g)		Fertility (%)	
Source	d.f.	M,S.	F.	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
First crop											
Treatments	8	2.17	—	22.93	1%	3.3985	1%	0.1371	1%	3.5465	—
Single vs. Split	1	1.18	—	16.17	—	4.8473	1%	0.1882	5%	0.14	—
Within Split	7	2.31	—	23.90	1%	3.1916	1%	0.1298	1%	4.0331	—
Years	1	308.35	1%	352.45	1%	22.1002	1%	9.5557	1%	41.7698	5%
Treatments x Years	8	0.88	—	6.21	—	1.0286	1%	0.0471	—	6.8168	—
Single-split x Years	1	1.77	—	8.35	—	1.1165	5%	0.0158	—	0.1540	—
Within spli tx Years	7	0.75	—	5,90	—	1.0161	1%	0.0516	—	7.7687	—
Error	48	1.10		6.99		0.2633		0.0414		5.8651	
Second crop											
Treatment	8	1.55	1%	32.66	5%	0.51	—	0.12	—	21.38	1%
Single vs. Split	1	2.13	5%	7.80	—	0.64	—	0.14	—	26.87	5%
Within Split	7	1.46	1%	36.21	5%	0.49	—	0.12	—	20.60	1%
Years	1	51.68	1%	1,932.35	1%	16.62	1%	0.25	—	117.68	1%
Treatment x Years	8	0.71	—	20.44	—	0.67	—	0.07	—	5.68	—
Single-split x Years	1	0.09	—	3.18	—	3.03	1%	0.05	—	4.94	—
Within split x Years	7	0.80	—	22.90	—	0.30	—	0.07		5.79	—
Error	48	0.38		13.67		0.38		0.09		4.12	

* Analysis was based on data of the same crop season of 1965 and 1966.

It should be pointed out that the results summarized in this paper are indicative of the effect of time of application of fertilizers on one rice variety grown under one set of conditions. The Chianung 242 variety might respond differently on different soil types and under different climatic conditions.

SUMMARY

The effects of time of fertilizer application on yield, components of yield, and some important agronomic characters of rice evaluated in 1965 at the Chiayi Agricultural Experiment Station are summarized.

Treatment C with nitrogen fertilizer top-dressed at maximum tillering stage and treatment F, at both maximum tillering and panicle initation stages produced the highest yields in both crops. The yield increases appeared to be due largely to the increase of panicles per hill. Top-dressings of nitrogen fertilizer before maximum tillering stage did not contribute to yield increase. The effects of applying nitrogen fertilizer at heading stage and split application of potassium fertilizer were not evident in this experiment.

Early application of nitrogen fertilizer generally produced more tillers per hill and larger leaf area index in the first crop whereas late application of nitrogen fertilizer resulted in better growth of rice plant in the second crop. There was an indication for a tall and late heading plant to be associated with high yielding ability.

Significant interactions between treatments and years were observed in panicle length and number of grains per panicle in the first crop, and grain yield and number of panicles per hill in the second one.

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肥料分施對水稻產量，產量構成因素，及其他農藝性狀之效果(四)

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摘　要

本文係報告嘉義農業試驗分所於民國54年第1期作起至民國55年第2期作承辦全省性水稻肥料分施試驗之綜合結果。

在水稻分蘗盛期施用氮肥1次之處理3及在分蘗盛期及幼穗分化期各施用1次氮肥之處理6，其產量在第1、2期作均較其他處理爲高，其增產原因爲每株穗數之增加。在分蘗盛期前之追施氮肥，效果甚微。又在齊穗期之氮素追肥及鉀肥之分施，在本試驗亦未見成效。

在第1期作早施氮肥能增加每株分蘗及葉面積指數，而在第2期作，則以後期追施氮肥之稻株發育較佳。稻株高，而生育日數長之處理，似較高產。

第1期作之穗長與每穗粒數，其處理與年份之交感作用達顯著水準，而第2期作之產量及每株穗數之交感亦極顯著。餘外性狀，均未見有顯著交感作用之存在。